LCA Methodology

Life-Cycle Critical Review! Does It Work?

Implementing a Critical Review Process as a Key Element of the Aluminum Beverage Container LCA

[1]James Fava, [2]Steven Pomper

[1]Roy F. Weston, Inc., 1 Weston Way, West Chester, PA 19380, USA
[2]ALCAN Aluminum Ltd., 1188 Sherbrooke Street West Montreal, Canada H3A3G2

Corresponding author: Dr. James A. Fava

Abstract

This paper describes the incorporation of an independent review process into a life-cycle inventory (LCI) study. The peer review process was the first application of the three-stage review of an LCI. The three stages are: Review of the Goal and Scope Definition, performed when the study plan has been established; Review of the Data-Gathering Methodology, performed after the data have been collected; and Review of the Final Report, performed after the draft report has been written. The purpose, process, and benefits of the review are discussed. Examples of benefits include the incorporation of a process to select ancillary materials for inclusion in the study, and a sensitivity analysis rationale.

Keywords: Aluminum production, review process; critical review, LCI; data-gathering methodology, review; environmental management; expert panel, LCI; expert review, LCI; goal and scope definition, review; ISO standards, LCA; LCA; LCI; Life Cycle Assessment (LCA); Life Cycle Inventory (LCI); pollution prevention strategies; product life cycle; review process, LCI; sensitivity analysis, variance index, LCI; SETAC guidelines, LCA

1 Introduction

Life-Cycle Assessment (LCA) promises to provide appropriate answers to questions regarding the environmental performance of a product system. More specifically, a Life Cycle Inventory (LCI) will provide a quantification of the resources consumed (both energy and material) and environmental emissions to air, water, and land throughout the life cycle of a product system (from resource extraction through to waste disposal – earth to earth). When suitable interpretations of the inventory results are completed, an LCA study will highlight the most significant potential for improving a product system from an environmental perspective. In comparative studies, LCA is a tool that identifies the relative strengths and weaknesses of one product system versus another product system serving the same function.

A product system interfaces with the environment throughout all stages of its development, from extraction of natural resources to obtain materials, to fuels used in manufacture, to the product's ultimate disposition. The concept of Life-Cycle Management is illustrated as a cycle from raw materials acquisition to final disposition, including recovery, reuse, and recycling (→ *Fig. 1*).

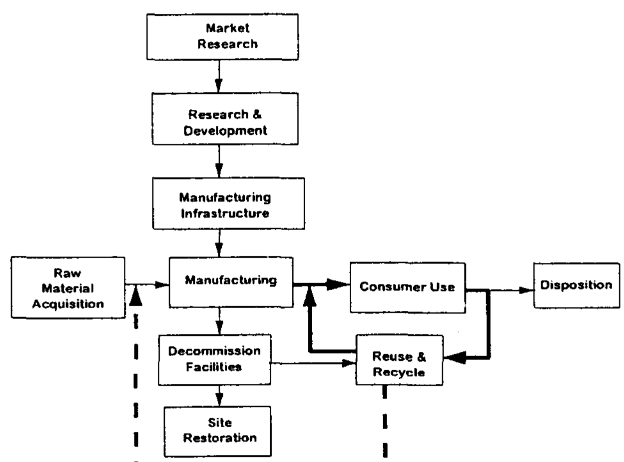

Fig. 1: Life-Cycle Management Concept

Pollution prevention strategies are being developed to maximize the continued use of products and materials while minimizing production environmental releases as well as energy and material consumed during the entire product life cycle. Although this analytical tool offers significant potential benefits to companies to prioritize environmental improvements and to differentiate the environmental attributes of their products, considerable controversy exists regarding its use. There have been instances when an LCA study concluded that Product A was environmentally superior to Product B, while another LCA study found the opposite to

be true. LCA practitioners have long understood that LCA study results are only as good as the questions and modeling assumptions used in the analysis. An LCA study is goal-dependent; it requires careful consideration of the factors/impacts to be studied and requires numerous assumptions to be made when modeling a product system.

Life-Cycle Critical Review has been incorporated as a requirement in the current drafts of the International Organization for Standardization (ISO) standards for LCA. The focus of these ISO standards is to require a critical review in cases where a comparative assertion[1] is being made. Some ISO LCA committee experts have questioned the practicality and value of conducting such reviews, while others believe that such reviews should be performed for all LCA studies, regardless of the intended use of the study. Moreover, the Society of Environmental Toxicology and Chemistry (SETAC) and the U.S. Environmental Protection Agency (EPA) have developed peer review guidelines for use by commissioners and practitioners of LCI studies.

The primary goals of a critical review are to provide an independent evaluation of the LCI methodology, and to provide input to the study proponents on how to improve the quality and transparency of a study, whether the intended use of the study is comparative or not. It was for these reasons that three aluminum producers were the first to apply a three-stage review process on an LCI study. This paper discusses the experiences of this LCI study by describing the:

- Purpose of the review
- Review process
- Review process results
- Benefits of the review process

2 Purpose of the Review

In 1991, ALCAN Aluminum Ltd., Aluminum Company of America, and Reynolds Metals Company decided to jointly conduct an LCI on the North American aluminum beverage can. It will be referred to as the ALCAN, Alcoa, Reynolds Metals (AAR) Study. The purpose of this study was to provide the participating companies with a detailed inventory that will serve as a baseline for improvements and to provide a definitive outline of the most current performance in the aluminum beverage can product system (aluminum production, can manufacturing, can filling, recycling, and disposal).

The study followed the guidelines and principles set out in the SETAC publication entitled "A Technical Framework for Life Cycle Assessment", January 1991 [1] and the EPA document "Life Cycle Assessment: Inventory Guidelines and Principles" [2]. The study was directed by Dr. James A. Fava and was reviewed by an independent expert panel.

[1] Comparative Assertion – An environmental claim made publicly regarding the superiority of one product versus a competing product that performs the same or similar function

The study cost approximately $250,000 U.S., including $30,000 U.S. for the review panel activities. In addition, data collection activities at the operating plants averaged approximately 3 person-days per reporting location. More than 500,000 data points were generated during the study, including data collected from more than 60 sites in six countries and four continents. The timetable for the study was as follows:

- November 1991 – AAR agrees to jointly conduct study
- December 1991 – Project consultant selected
- January 1992 – Review panel chair identified; peer review; chair selects other panel members
- February 1992 – Definition of goal and scope completed
- May 1992 – Stage I review completed
- February 1993 – Stage II review completed
- March 1993 – Data collection completed
- February 1994 – Draft final report
- March 1994 – Stage III review completed
- May 1994 – Final report issued

3 Critical Review Process

3.1 Review panel selection

The project consultant was given the mandate to select the chair for the review panel. The selection criteria of the review panel chair and panel members included the following factors:

- A reputation for independent study
- Experience with the technical framework, design, and/or conduct of life-cycle studies
- A willingness to interact positively as part of the review process

The responsibilities of the review panel chair included the selection of the other panel members, the definition of the review process, and the preparation of the review panel reports. Mr. Bruce Vigon, Battelle, accepted the position of chair and selected Dr. Richard Denison, Environmental Defense Fund, and Ms. Jacinthe Sequin, Environment Canada, as panel members.

3.2 Review process

The primary goal of the peer review was to provide an independent evaluation of the LCI methodology. The evaluation examined the methodological requirements found in SETAC and EPA reference documentation.

The following assumptions were key to the conduct of the review; the project consultant, WESTON:

- Did not participate in the peer review panel
- Was available to explain the study approach and assumptions and to answer questions

- Reviewed recommendations from the review panel and forwarded them to the aluminum companies
- Addressed the comments made by the peer review panel and made specific revisions to the LCI methodology and study report

Because of the confidentiality of some LCI data, all confidential agreements were in place before the start of the peer review, or at least before the receipt of materials containing confidential data.

The peer review process followed a three-stage approach, outlined as follows.

Stage 1: Review of the Study Purpose, Boundaries, and Data Categories – A review of the study purpose, system boundaries, and data categories was conducted after the definition of goal and scope. The objectives of Stage 1 were to ensure that the purpose of the study was clearly defined in terms of what is to be analyzed; ensure that data categories to be included within and excluded from the system boundary were identified; understand how the results of the study will be used; and understand how the result will be documented and distributed.

Guidelines for the evaluation included practical questions that were addressed by the following review panel:

- Are the study objectives, purpose, and scope clearly identified?
- Are the boundary conditions clearly stated? Do they reflect the current state-of-the-practice?
- What are the assumptions used? Are they reasonable and justified? Are they clearly stated?
- Are the data quality characterization procedures reasonable? Appropriate?
- Are data categories identified? Are they reasonable and justified?
- Are the potential sources of data identified? Are they reasonable or are other sources potentially available?

The comments were prepared, reviewed by the entire panel, and submitted to WESTON following completion of Stage 1 review. The Stage 1 process resulted in an integrated set of comments to ensure that the purpose, scope, boundaries, and data categories were reasonable.

Stage 2: Mid-Project Review – The mid-project review occurred after data had been collected and normalized by unit process and for the product system as a whole. The Stage 2 objectives were to review the formal responses to recommendations from the Phase I activity; confirm the categories to be included in the study; verify adequacy data collection procedure and the data integration model; and assess the adequacy of data quality assessment. The guidelines for this stage included:

- Are the data categories appropriate for the stated goal of the study? Is the level of aggregation reasonable and justified?
- Are the data sources clearly stated? Are they reasonable and justified?
- Is the methodology for data calculations clear? Is it reasonable and justified?
- Are the data assumptions clearly stated? Are they reasonable and justified?
- Has data quality been evaluated?

The results of Stage 2 were comments to improve the data quality and the assumptions made.

Stage 3: Review of the Draft Final Report – This review occurred after the data were summarized and presented in the final draft report. The Stage 3 review objectives were to review the formal responses to the Stage 2 recommendations; confirm that the observations and conclusions from the study are consistent with the stated purpose; and assess overall study quality and how the study meets the data quality specifications that are relevant to the stated purpose. The guidelines for this stage included:

- Was the methodology used identified? Was it of sufficient detail for someone to repeat the study?
- How were the data aggregated, summarized, and presented?
- Were the conclusions appropriate based on the data and analysis?

The results of Stage 3 were specific comments to improve the transparency of the methodology and to clearly communicate the limitations on the use of the study results in relation to data quality and scope.

4 Critical Review Process Results

The results of applying the critical review process were seen at each of the three review stages and are summarized as follows:

Stage 1: Review Results

- Comprehensive documentation of the purpose and intended uses of the study
- Understanding of the unit processes in the product system
- Development of the data categories to be employed in the study
- Establishment of a quantitative process for determining the inclusion of ancillary material flows (see "System Boundaries")
- Establishment of the data quality assessment framework (see "Data Quality")

Stage 2: Review Results

- Establishment of data categories and supplementary information to support the level of aggregation
- Confirmation of the mass balance on material flows
- Verification of the application of data collection templates and the data integration model

- Validation of the data/assumptions on energy databases and fuel-related emissions factors
- Establishment of quantitative process to determine the sensitivity of the results based on the data quality (see "Sensitivity Analysis")

Stage 3: Review Results

- Assessment of overall data quality and the attainment of data quality goals
- Establishment of a quantitative process to prioritize process improvement opportunities (see "Process Improvement Analysis")
- The Stage 3 peer review report identified more than 60 specific recommendations on the content of the report and the manner in which the data and study results were presented

For each of the four areas previously identified, where advances to the understanding of the LCI methodology were developed, additional explanation is presented here. The intent is to enable the reader to appreciate the value that a critical review can play in designing and conducting LCI studies.

4.1 System boundaries

A major source of debate concerning LCI studies is that several different studies performed on the same systems have generated different results and reached different conclusions. While these differences can be explained by the assumptions and modeling activity, a major difference can and does occur as a result of the how the system boundary is defined.

Even if the studies clearly define the main process flow and consistently apply the life-cycle concepts and guidelines, the studies may still arrive at inconsistent results. The reason for this inconsistency stems from the ancillary material flows that are included in the scope of the study.

Study teams are often faced with a trade-off decision on what to include. In their pursuit of conducting a comprehensive study, they are normally constrained by the resources available, both in terms of time and money. In many cases therefore, the examination of ancillary flows is based on intuitive judgments about the significance of certain ancillary inputs. In most cases, the selection of which ancillary flows to include has been based on data availability. Some practitioners have developed simple decision rules to examine the mass contributions of the ancillary materials as a means of semi-quantifying the inclusion decisions.

The aluminum beverage can study relied on the recommendations of the peer review panel, who proposed the use of a more rigorous analysis to determine which ancillary materials should be included. The main features of the analysis are to evaluate the "life-cycle" mass contribution, energy contribution, and environmental relevance of the ancillary material flows in the system. The main production streams for the aluminum beverage can are shown in **Figure 2**.

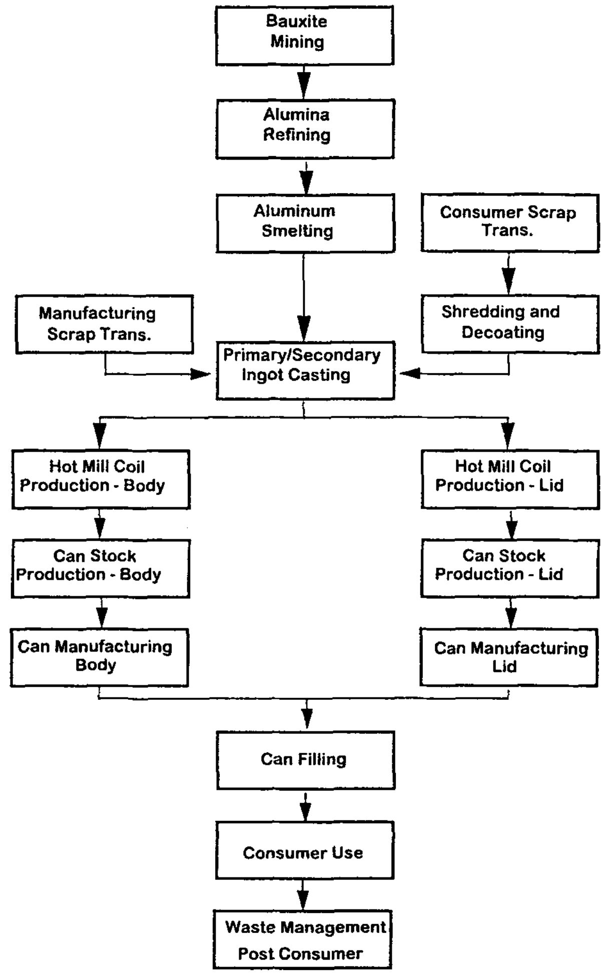

Fig. 2: Primary process flow for the North American aluminum beverage can

The analysis used the inputs on the initial data input sheets from several reporting locations to estimate the mass contribution of each ancillary material flow in each unit process. The reporting locations were asked to identify any materials flow that constituted more than 1% of the mass of output products from the unit process.

The mass contributions represented the production weighted average value for each ancillary material in each unit process. An overall mass balance was performed to determine the mass contribution of each ancillary material to the overall system studied. A decision rule was established to include a minimum of 90% of the mass contribution of ancillaries identified in the data input sheets.

Once the mass balance was performed, estimates of the "life-cycle" energy values were established for each ancillary material. The energy estimates represented the total energy required to manufacture and deliver the ancillary materials for use in the system. The data values were taken from published LCA studies on the materials involved. Where published information was unavailable estimates were made

using surrogate information. Similar to the mass analysis, a decision rule was established to include a minimum of 95% of the energy contribution of the ancillary identified in the data input sheets.

Finally, an assessment of the environmental relevance of the ancillary materials was performed. A preliminary inventory was completed using the inputs from the data input sheets for the main process flow excluding ancillaries. The preliminary inventory established a set of initial inventory values for each of the environmental releases. A threshold for each environmental release was then calculated based on the 15% guideline discussed by the peer review panel. That is, if the initial value for a data category was 10 pounds (lb) per 1,000 lb of cans, then an ancillary would be included in the scope if its contribution was greater than 1.5 lb for that data category, based on its mass contribution to the overall system.

For example, assume that 1.0 lb of soda is used in the smelting process to produce 1,000 lb of cans and that the preliminary particulate loading from the system is 10 lb per 1,000 lb of cans. The system to make soda would have to generate 1,500 lb of particulate per 1,000 lb of soda before this ancillary would be deemed relevant for particulate. If particulate generated in the soda production system is less than the threshold value of 1,500 lb and the other environmental releases in the soda production system are less than their corresponding threshold values than soda would not be considered environmentally relevant.

Following the analysis the ancillary materials were classified into one of three categories: **primary ancillary, secondary ancillary, and negligible ancillary material flows.** The classification was based on the aforementioned decision rules and the availability of reliable data. Primary ancillary materials include all materials that result in mass contributions of at least 90%, or energy contributions of at least 95%, or have environmental releases that exceed the threshold values.

The result of this analysis was to include a cumulative 99% of the mass contribution identified and 99.6% of the energy contribution to the overall beverage can life cycle.

4.2 Quality

A comprehensive LCI involves the collection and integration of hundreds upon thousands of pieces of data regarding the product, process, or activity under study. Depending on the scope of the study, information is gathered from different companies and countries. As such, it is essential that the management of **data quality** is an integral part of the overall process. Life-cycle data quality was the subject of a workshop and seminar conducted by SETAC in October 1992 [3]. Within that forum, data quality was defined as:

"...the degree of confidence one has in the individual data input from a source and in the data set as a whole, and ultimately in the decisions based on the life cycle study using such data as input."

To assess and therefore maximize the data quality in a study, a study team can use a number of **data quality indicators** that may be quantitative or qualitative in nature. The following sections describe the types of indicators used and how they were applied in the aluminum beverage can study. In the following description of the data quality indicators, precision and completeness are quantitative data quality indicators while the remainder are qualitative data quality indicators.

Precision – This is a measure of the spread or variability of the data set values about the mean of the data set. For each data category, the mean and the standard deviation of reported values have been calculated and reported for each unit process in the life cycle. These precision measures were later used to assess the uncertainty of reported values and aid the sensitivity analysis of the study results.

Completeness – The completeness of a data set is a measure of the primary data values used in the analysis divided by the number of possible data points associated with a data category. For example, in the aluminum smelting unit process, there were seven aluminum smelters providing data to the study. The completeness for the data category "effluent treatment" under the Solid Waste section was 71.4%, (i.e., five out of seven smelters reported values that were used in the analysis). The completeness measure was calculated for each data category in each unit process. As with the precision measure, completeness also was used to assess the uncertainty of the reported values.

Consistency – Consistency is a qualitative understanding of how uniformly the study methodology is applied to the various study components. This quality measure is one of the most important to manage in the inventory process. Steps must be taken to ensure consistency; the most significant step is communication. In a study of different companies to collect data from over 60 different sites in different countries and continents, there must be a clear understanding of what data are being requested, and how data re measured, reported, and used.

A Data Availability Survey was beneficial in achieving a common understanding of the unit process boundary conditions and the outline of data categories in the system. Each data category was described so that the reporting location knew which data values were to be reported under the various data categories. Data collection was aided by the use of a standardized Data Input Sheet.

A **Glossary** was appended to each data input sheet describing what was to be included under each data category. This glossary included a standard set of weights and measures to be used as well as comments about the measurement locations. The reporting locations were encouraged to describe fully what they included in their data values and how

they were measured, and where possible, highlighting the sampling and analysis protocols that were employed. These descriptions were used to verify data collection consistency between the companies.

Verbal and written communications flowed between the study team and the reporting locations, sometimes on several occasions to a single location, to verify data inputs. This verification process also involved a rigorous review of each data category for each unit process.

The process was managed by the consultant, WESTON, as the companies were prohibited by anti-trust legislation from sharing data of a competitive nature. This process is further described in the discussion on identification of anomalies later in this section.

Once the data were received and verified, the data integration and application of primary energy values and standard environmental factors for the various fuels were completed by the consultant through the use of a spreadsheet computer model. Each unit process for each individual company was treated in the consistent manner. This activity resulted in the generation of a production weighted normalized inventory result for each unit process that were then integrated based on the life cycle flow process inter-relationships between the various unit processes.

Overall the peer review panel concluded that a high level of consistency was achieved with respect to the approach taken to identify, collect, verify, and integrated data.

Applicability/Suitability – This measure refers to the relevance of the data sets within an analysis to the stated purpose of the study. This is commonly represented by an examination of the data sources, data types, age of data, and the technology employed in the processes being analyzed.

The study was based on actual 1991 performance in the unit process locations that provided input to the manufacture of the aluminum beverage can. The data sources, data types, and age of data are the most applicable available for the stated purpose of the study.

Representativeness – This indicator measures the degree to which the data values used in the analysis present a true and accurate measurement of the average processes under examination. The degree of representativeness is normally judged by the comparison of values determined in the study with existing reported values in other analyses or published data sources dealing the subject matter. Any major variances identified should be examined and explained.

The analysis focused on the geographic, temporal, and technological dimensions of the product system.

Comparability – Comparability refers to the degree to which the boundary conditions, data categories, assumptions, and data sampling and quality assurance protocols are documented to allow for comparison of the results and conclusions reached for different components of an analysis.

To the extent possible, the study documented all of the characteristics necessary to achieve a high level of comparability. Limitations exist on those matters that were of a proprietary nature to the companies involved. Not only were these matters constrained by the companies desire to maintain competitive advantage over one another, they also were limited by anti-trust regulations. In all other instances, the study documented pertinent characteristics within the scope and intent of the study.

Identification of Anomalies/Missing Data – Anomalies are extreme data values within a data set. These values are normally identified through statistical analysis and/or as the result of expert review. Whenever anomalies or missing data have been identified and either removed from the data set or replaced by a calculated value, they must be identified in the results of the analysis. These data values usually exist as a result of misinterpreted requests for data input, misreported data values, improper analysis of data samples or simply not available when the data values were originally submitted by the reporting locations.

The analysis of the reported data values was initially conducted by the consultant. Through the use of the computer spreadsheet the consultant identified data values that were considerably different or well outside the acceptable range of other reported values. In addition, the consultant flagged values that were missing from each reporting location.

The anomalies were identified during a comprehensive review of each data category for each unit process. The study team representatives took a listing of anomalies back to the reporting location or in house company experts to determine their validity for inclusion in the database. Where the anomaly could be explained in terms of a process upset or accidental release, they were left in the database. If an explanation could not be found or a reporting error could not be corrected, the anomaly was removed from the database and duly documented.

Once the anomalies were dealt with, missing data were evaluated to determine the appropriate inputs for the data category. A basic guideline for the study was that each data category for each reporting location must have:

- An acceptable reported data value
- A zero value, where applicable
- A calculated value based on the average of reported
- Values from unit processes with similar technology

These guidelines were consistent with those offered by SETAC and the peer review panel report.

Reproducibility – This measure describes whether sufficient information, both methodological and data values, exists to permit someone to independently perform the calculations and reproduce the study results.

This quality measure is used when some form of public claim is to be made regarding the results of a study. Since the purpose of this study is primarily oriented to internal im-

provement activities, this quality measure was not a primary objective of the study team. In addition, the concerns expressed regarding anti-trust also precluded the attainment of the level of transparency needed to satisfy its' use in the public arena.

Accessibility/Availability – This measure reflects the degree to which information regarding the study has been made available or accessed by either internal experts and/or external reviewers for examination of the methodology and data values.

As previously discussed in the section on identification of anomalies, the data values have been extensively reviewed by the reporting locations and in-house experts. The aforementioned sections above explain the limitation on further review of data values.

4.3 Sensitivity analysis

The current practice within LCI demands that the data be tested to ensure the robustness of the model and to test how data input uncertainties might influence the outputs from the study. The mean and standard deviation of the independent variables were reported as part of the results from each unit process in the study.

Sensitivity studies were performed to test the effect of key assumptions on the results of the model. Sensitivity analyses were performed on input data categories having either high uncertainty or large effect on the study results.

A **variance index** was calculated for each material input, energy input, and environmental release (to air, water or solid waste). For a given item, the sensitivity index is a function of the mass or energy of the item per functional unit, the calculated precision and completeness of the data set for that item, and a set of **sensitivity factors**.

The conceptual thinking behind the variance index suggests that the arithmetic product of the percentage contribution and importance (sensitivity factor) of a data category will help to highlight the significance of the data category to the overall results. If a data category has 100% completeness and identical data values, the variance index is an indication of the importance and contribution of that unit process data category. Anything short of full completeness and/or any variation in the reported data values serves to increase the variance index.

Selected items that have a high variance index because of data variability related to technology or other real differences between the individual locations were eliminated from the list. For example, transportation energy for bauxite mining was eliminated from the selected list for sensitivity analysis. The variability of this data category was directly related to the location of the bauxite mines in relation to the alumina refineries.

Assuming five raw material inputs, four energy inputs and 25 emissions per unit process, this results in up to 800 independent variables that could impact the results of the inventory calculation. The brute force approach of changing all input variables to determine the effect on the inventory results is neither cost effective nor necessary. Therefore, a method to identify the important few variables that should be included within the sensitivity analysis was developed.

In an attempt to prioritize the inputs by "importance," a new variable was created. This variable, called the Variance Index, serves to highlight those data categories that:

- Strongly influenced the results of the study
- Have a high variance as a percentage of the mean
- Have a low coverage in the input values
- Potentially have a significant contribution to the systems mass, energy, or environmental relevance

Three sensitivity factors were developed: mass contribution, energy contribution, and environmental relevance. Each data input category was assigned a value from 0 to 5 for each sensitivity factor. A value of 0 represents no impact, a 1 is little impact, and a 5 represents the greatest impact.

For example, when looking at the energy factor, the mass factor was set to 0, while the energy and environmental relevance factors each ranged from 1 to 5 (1 for insignificant impact, 3 for intermediate impact, and 5 for significant impact).

Calculations were performed to determine those data inputs that may result in the greatest variation to an overall data category result. The variance index was used to calculate the potential variation for a data category. For example, the variance index (VI) for coke consumption within the anode production process was calculated according to the following formula:

VI = PC X SF X VAR / COMP

where,

PC	is the percentage contribution to total mass (3.92% or 0.0392)
SF	is the sum of sensitivity factors (e.g., rating from 0 to 5 for mass (3) and energy (3) contribution, and environmental relevance (2) for a total of 8)
VAR	is the standard deviation/mean of the data set (.103)
COMP	is the completeness of the data set (100% or 1.0) (number of samples/ number of possible samples)

The variance index for coke is:
0.032 (i.e., 0.0392 X 8 X .103 / 1.0).

The VI has no physical significance other than to highlight relative significance of inputs with:

- High raw material, energy, or emission factors
- High variance
- Low percentage coverage on the input data
- Large contribution to the total within individual data categories

The VIs were calculated for all raw material inputs, all energy inputs, and all environmental loadings for each of the unit operations. The VIs were grouped into three categories (i.e., raw material inputs, energy inputs, environmental loadings) and then sorted from high to low for each of the three groups.

Each data category with a VI greater than a specified value was identified. The specified value was set at 0.010, which represent a 1% impact on the contribution to the overall system for a specified data category. The selected data categories were then analyzed to determine a representative "minimum" and "maximum" data value for that data category.

The low-sensitivity results set specified data categories to the minimum values for those data categories based on similar technology. In the case of coke consumption for anode production, the lowest reported value for prebake and soderberg anodes selected in the low sensitivity scenario. Similarly, the high-sensitivity results used the maximum coke consumption values.

Two model scenarios were then run in the computer model. Inputs were first set at the "minimum" data set values and then at the "maximum" data set values to test what impact this would have on the output from the model.

4.4 Process improvement analysis

The aluminum beverage can study identified several areas where reductions in raw material and energy consumption as well as environmental loadings could be achieved. The study was used as a benchmark to highlight specific areas where each of the individual companies can improve. Comparison of the individual company reports to the composite identified areas of both internal strengths and weaknesses within the energy consumption and environmental loadings of the various unit processes.

The potential for improvement was illustrated in the sensitivity analysis. If each operating unit within each company achieved the low-sensitivity values and assuming all other factors are held constant, the effect of achieving the low sensitivity values would reduce all environmental factors by more than 10%.

To prioritize the process improvement efforts, an "improvement potential index" of the data categories selected for the sensitivity analysis was determined. This index ranks the various systems inputs and outputs according to the following formula:

Improvement Potential = Standard Deviation/Mean Contribution

For each of the data categories, the standard deviation of the input or output was divided by the mean of the input or output and multiplied by the contribution that the input or output value had to the data category. The improvement potential index was then sorted from the highest to lowest value in three categories: material consumption, energy consumption, and environmental releases. Based on this analysis, the individual aluminum companies were able to identify the greatest opportunities for improvements within those categories.

5 Benefits of the Review Process

The latest increase in the use of life-cycle studies has received considerable attention both in the academic and policy arenas. Such attention has fostered the preparation of several well-written documents that explain principles and guidelines for conducting life-cycle studies. These reference materials generally present the methodology in relatively simple conceptual terms. They rarely provide detailed prescriptions on how to execute the process of establishing the definition of the goal and the scope of the study; how to develop data collection techniques that ensure consistency; how to model the product system and provide a clear understanding of the limitations and constraints of the model; or how to present the results in a modeling fashion that is consistent with the goal and activities.

In the context of the aluminum can study, the peer review process provided precise instructions in numerous situations where the documented approaches found in the reference materials could not possibly offer such practical inputs. The study team made numerous recommendations to improve the quality of the study. The methodology used in this inventory was based on those recommendations coupled with the SETAC [1] and U.S. EPA guidelines [2].

Specific methods helped the study group determine the most significant inputs and outputs from the product system. This was accomplished with the scoping exercise that defined the cumulative contribution of ancillary materials to the product system. This exercise prevented valuable resources being spent on insignificant inputs and outputs. The analysis also provided a foundation on which comparisons could be made to other published life-cycle studies on the aluminum beverage can system. For example, it highlighted that ancillary material flows represented over 20% of the system material and energy flows and a corresponding level for environmental emissions.

The review process identified the need to measure the quality, both quantitatively and qualitatively, of the data collection processes and the data itself. Such measures provided confidence to the study team, that the data inputs truly represented the system being modeled. The quantitative measures helped the study team develop various sensitivity analyses that examined the effect of data uncertainty on the study results.

The study team, in conjunction with the peer review panel and the consultant, developed a sensitivity analysis procedure that highlighted the uncertainty of the data inputs. Most life-cycle studies tend to report single values for the data categories presented in the study. These single values are often misleading since there is a range of potential results due to variability in performance from location to location and over time. Traditional sensitivity analysis would vary the result for one independent variable while holding other variable constant. Even with the advent of computer processing, such exercises are very cumbersome and are often not completed. In the aluminum can study there were approximately 800 independent variables. A procedure was developed to identify the most significant.

With the range of opportunities presented by the sensitivity analysis, the participating companies still had a significant

task in identifying where to focus their improvement efforts. The study team developed a prioritization procedure to define the most promising process improvement potentials.

6 Conclusion

Peer review has been a time-tested technique within the scientific community to provide valuable inputs to leading edge developments. Scientists and researchers recognize that comments from a peer review serve to validate the protocols of their efforts and ultimately improve the credibility of the findings. In the context of LCA, peer review or "critical review" does improve quality and transparency of an LCA study as highlighted in the aluminum beverage can example.

7 References

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JLCA Corner: Activities of the Life-Cycle Assessment Society of Japan (JLCA)

Mamoru Morimoto

Manager, Research and Planning Division, JEMAI, Hirokohji NDK Bldg., Ueno 1-17-6, Taitoh-ku, Tokyo, Japan 110;
e-mail: f7370651@ca.aif

On the occasion of the JLCA Meeting held on June 19 and 20, the LCA National Project has been planned which will start in April 1998. It is financially supported by MITI (Ministry of International Trade and Industry). The Project will consist of members from industry, university and research institutes. They cooperate for five jears. Main subject areas are: Development of an Inventory Data Base; LCA Case Studies; LCA Application Guidelines; LCA Education and Propagation; Inventory Analysis Methodology; Impact Assessment Methodology

JLCA Policy Statement on LCA

The Life Cycle Assessment Society of Japan (JLCA), established in October 1995 with about 250 participating organizations from industries, government and academic sectors, has worked actively for the past 18 months through its three expert committees and eight working groups.

After studying LCA methodologies and their applications, and the requirements and direction for the public inventory data base in Japan, the Forum put together the results into an LCA Forum Report, a proposal for promoting LCA, and a Policy Statement on LCA.

1. In corporation with other parties concerned in the society, industries should incorporate LCA into various business activities such as planning and designing a product, and setting priorities for improving production processes, wherever possible.

2. Amid the ever growing interest in global environmental issues, the concept of "a sustainable development" has now been upheld as one of the most important issues to the addressed and it will be mandatory to incorporate this concept into every social activity. In order to give LCA a due social standing a sone of the measures to achieve "a sustainable development" in a broader framework, it is indispensable to develop an efficient LCA method and to construct a data base. Also required is the process of a series of practical application and review of this LCA method which will be efficient enough and consequently attain public recognition as a fair and credible environmental assessment tool.

3. A popular practice of LCA would not be realized without the construction of various data bases and a simple system for their application. Here, the provision of reliable data bases by industries and the disclosure of LCA results are necessary. To facilitate this, the establishment of a national data base agency and a permanent LCA organization upgrading the present JLCA is required.

4. The basic concept of LCA has already been established, although its methods are still in the process of development and an evaluation of impact assessment is yet to be formulated. Results of LCA which we use at present are strongly influenced by the kinds of preconditions laid down and the nature of the data employed. For this reason, in case of using LCA for such purposes as comparting environmental impacts of material and its substitution, utmost care is necessary to avoid any undue distortion of the facts. Moreover, an order of priority to be set on environmental elements and issues to be addressed changes in accordance with the kind of society, place and time. It is therefore necessary to be aware that using the LCA method alone for making a judgement on any complicated issues entails a danger to misjudge.

5. In addressing the global environmental issue in future, it will be undoubtedly required that, in addition to the introduction of LCA methods by the industries concerned, all walks of people – not only industrialists, but also ordinary citizens, accept a life-cycle manner of thinking and review their own life style accordingly. Also indispensable is to promote an enlightening of people on the knowledge of LCA so that they may be able to take action. For this end, all of the administrative authorities should act in concert friendly to the ecology, and to implement appropriate measures.